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TROPICAL YAMS AND THEIR POTENTIAL

Part 1. *Dioscorea esculenta*

Agriculture Handbook No. 457

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
U.S. Agency for International Development

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PREFACE

The feeding of future generations requires a knowledge of the individual crop plants of the world and their potentials. Crops can be recommended for use in particular regions only on the basis of potential yield, the costs of production, the food and feed value of the crop, and the way the crop can be processed or otherwise used. For most of the major food crops of the world, a body of information is already available. However, tropical roots and tubers, which are widely used as staple foods, have been largely neglected. Only in recent years has an awareness been growing of the potential of these crops to supply large amounts of food in relatively small amounts of space.

Yams are the second most important tropical root, or tuber, crop. The annual production, perhaps 25 million tons, places them second in importance to cassava. But yams are better food than cassava, and while they are usually thought to be more difficult to grow, under some conditions yams outproduce cassava. Yams fill an important role in the diet of many areas of the Tropics—a role that can increase in importance. That role and its potential are not, however, well understood.

The yam is not a single species. Perhaps 60 species have edible tubers; of these about 10 species can be considered crop plants. The literature concerning these species is widespread but fragmentary. This is the first of several Agriculture Handbooks in which the major species of yams are individually treated in order to bring the investigator as well as the agriculturalist up to date with respect to the status of these important plants. This is part of a research effort cosponsored by the Agricultural Research Service of the U.S. Department of Agriculture and the U.S. Agency for International Development to introduce, evaluate, and distribute better yam varieties.

rec'd 5-18-72 - Dr. Schubert

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TROPICAL YAMS AND THEIR POTENTIAL

Part 1. *Dioscorea esculenta*

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INTRODUCTION

Of the many edible yams found in the Tropics, the lesser yam, *Dioscorea esculenta* (Lour.) Burk., ranks third in production and utilization. Only the West African yam, *D. rotundata* Poir., and the Asian greater yam, *D. alata* L., are more widely used. *D. esculenta* is widely distributed and well known throughout the Tropics, but it is best known and most used near its origin, Indochina, and in adjacent islands, including Papua New Guinea and those of the Pacific Ocean. Some of the characteristics of this yam recommend it for wider planting, but it also has several severe disadvantages, which might limit its potential as a commercial crop. On the other hand, recent collecting efforts suggest that the best forms of this species have only now been obtained and that the potential is greater than had previously been realized.

History and Origin

Vavilov (*10*)[1] considers that *D. esculenta* was domesticated in Burma or Indochina (Indian center of origin). However, the species is so ancient that few wild forms are known. Burkill (*3*) describes several wild varieties from New Guinea and the Philippine Islands and suggests this as the center of origin of the species. Feral forms evidently occur on some islands of the Pacific and in India. Ting and Chi (*9*) mention accounts of cultivation of this species in China in the second and third centuries A.D. and maintain that it was an especially important staple food in southern China from the 2d to the 11th century. Burkill (*4*) summarizes the distribution and nomenclature of this species from India through Southeast Asia to the islands of the Pacific. There is little doubt of its use for hundreds of years there. The species has also reached the small islands of the Pacific, where it is widely used, but has never become a staple (*2*).

Geographic Distribution

The lesser yam is widely distributed throughout the tropical world, but it is little known or used except in southeastern Asia. Many forms can be seen in New Guinea. All of the collections obtained in West Africa appear to

[1] Italic numbers in parentheses refer to items in "Literature Cited," p. 18.

be similar or closely related. At least three distinct races have been collected in the Caribbean. The floras of most tropical countries mention the lesser yam, but it is seldom seen except in home gardens. The yam is common to many islands of the South Pacific, but appears to have been recently introduced on the eastern side.

BOTANY

Classification

D. esculenta (Lour.) Burk. has also been named *D. aculeata* L. and *Oncus esculenta* Lour. It is often called the lesser yam, the potato yam, or the Chinese yam. All of these common names are deficient in that they do not reflect the unique characteristics of the species.

D. esculenta belongs to the section Combilium, a monotypic section with no close affinities to any other cultivated species. In common with other yams, the lesser yam belongs to the family Dioscoreaceae, of which *Dioscorea* is the principal genus. The family is usually classified among the monocotyledons, although some evidence of a second cotyledon has been found. The family is characterized by rhizomes, usually reduced to a nodeless structure. Male and female flowers, usually on separate plants, are small and usually inconspicuous, although the inferior ovary may become quite prominent after fertilization. The floral pattern is based on sets of three.

Morphology

D. esculenta is a thorny, climbing vine, seldom more than 3 meters high (fig. 1). The stems are thin (1- to 3-millimeter diameter) and thorny to glabrous. They twist to the left in climbing. The leaves are alternate (or occasionally subopposite at the base of the stem) and orbicular, but with an acuminate apex and cordate base (fig. 2). The leaves are slightly rugose and finely pubescent. The petioles are thickened at their proximal end and are armed with four sharp prickles. The roots of *D. esculenta* often bear thorns, which may impede depredations by burrowing animals and wild pigs. These thorns, arising only from the fibrous roots and not from tuber-bearing stolons, may be very fine and sharp. Flowers are rarely seen on cultivated forms of this strictly dioecious species. On the presence or absence of thorns, two botanical varieties of the species have been distinguished, varietas *spinosa* (Roxb.) Prain & Burk. and varietas *fasiculata* (Roxb.) Prain & Burk. This distinction is artificial, for all degrees of thorniness can be found. The less thorny varieties have presumably been selected and represent the most evolved forms of the species.

The tubers superficially appear to be tuberized roots, but are swellings of stolons arising from the crown of the plant (fig. 3). The stolons vary in length from 5 to about 50 centimeters. The

FIGURE 1.—Mature vines of *Dioscorea esculenta*.

length is a varietal characteristic. Each stolon bears only one terminal tuber. About 4 to 20 tubers are borne by each plant. The number of tubers increases with favorable growth conditions, but is also related to the variety. The tubers vary in diameter from the size of a stolon to 20 centimeters in exceptional cases. In the Caribbean, tubers average 8 to 10 centimeters in length, with a diameter of 2.5 to 5 centimeters and a weight of 100 to 200 grams. Small tubers, useful as seed, are common. Very large tubers (as in the case of New Guinea varieties) reach 3 kilograms.

The tuber is usually shaped like a potato, although it is proportionally longer and narrower. Spindle shapes (such as those of the sweetpotato) are not uncommon. The tubers of better varieties are seldom branched, but in some primitive varieties branching is common (fig. 4). In a few varieties the tuberizing stolons grow upward, giving the tuber a crescent shape. The shape of the tuber is strongly affected by the soil and by stones or debris in the soil. Regular shapes occur in soft, loamy soil.

The surface of the tuber is smooth, with few to many adventitious, fibrous roots. A few depressions appear like the eyes of a potato. These are not the sites of preformed buds, but are local growth irregularities caused by minor injuries to the tuber. The

PN–3433

FIGURE 2.—Leaves of five *Dioscorea* species. Left to right, top to bottom: *D. esculenta*, *D. rotundata*, *D. trifida*, *D. bulbifera*, and *D. alata*.

thin bark is easily torn and may be marked with thin longitudinal cracks, which seldom extend beyond the cortex. These fissures, when extensive, can lead to fungal infections of the tuber. The cortex of the yam is thin (less than 1 millimeter) and usually white. Types with a pink or purple cortex have been described.

The flesh (parenchymatous tissue) of the tuber is crisp and uniformly fine grained. The color varies from pure white to dark cream or pale yellow. The raw flesh of a few varieties may irritate human skin. When the tuber is cut, gum oozes from the surface. This may be sticky and stringy. The surface may oxidize and turn brown within a few minutes. The tendency to oxidize is associated with variety, with size and age of tuber, and with region (proximal portions oxidize most rapidly). The tubers always contain fibers,

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FIGURE 3.—Clump of lesser yams on long stolons. Fibrous root system is seen above. (One-fourth actual size.)

PN–3435

FIGURE 4.—Unusual tuber shapes of the lesser yam.

but these may be soft and inconspicuous.

The starch of the tuber is very fine. Larger particles average about 0.50 to 0.60 microns in diameter. In addition, there are many very fine starch grains. The tuber contains 10 to 24 percent starch, and the proportion of amylose in the starch varies from 9 to 16 percent. Thus, the starch is much finer than that of cassava, sweetpotato, and most other yams, but the amylose content is quite low.

Cytology

Only a few chromosome counts of the lesser yam have been reported. The West African form of *D. esculenta* has 40 chromosomes (*7*). This is a common tetraploid number in the genus. Raghavan (*8*) reports counts of 90 and 100. Thus, highly polyploid races exist.

Because of the normal lack of flowering, breeding the lesser yam is not practical. Experience suggests that rapid improvement can be achieved through introduction and selection of varieties. This possibility has not been systematically explored. Within varieties, hill selection appears to be beneficial, especially during early generations. By selection of better hills, diseased and pest-ridden plants are gradually eliminated, and thus cleaner stocks are produced. Unless selection is continued, varietal stocks can decline again. A further possibility exists in ridding the plants of viruses. Probably all plants carry at least one virus that they tolerate very well. Since this virus appears to be peculiar to yams, once virus-free stocks are produced, it should be easy to maintain them in isolated plantings. Hill selection for tuber shape and for root-free tubers has not been effective.

VARIETIES

Wild Varieties

Most common forms of *D. esculenta* are cultivated varieties. Wild varieties have been described, but these appear to be mostly cultivated types that have been abandoned. Nevertheless, a few wild varieties have been found in Malaysia, New Guinea, and the Philippine Islands, and these differ from the cultivated and the feral types in having more vigorous foliage, larger leaves, longer stolons, and more fibrous tuber flesh. Although these races tend to be more thorny, thorniness is also related to other factors, such as the age of the plant and its size and condition. The shape of the tuber is a varietal characteristic. The wild types tend to be roundish or somewhat flattened and lobed.

New Guinea Varieties

Varieties are more numerous and varied in New Guinea than in any other area. In the Maprik

area southwest of Wewak, Papua New Guinea, about 80 varieties are distinguished by the local people. However, some characteristics, such as relation to family, may not be valid, and perhaps as few as 30 actual varieties exist. High-yielding varieties that require long growing seasons, with large tubers that store well, are the most common. Finer, improved varieties that mature earlier, have better eating qualities, but yield less, are also known. New Guinea cultivars have been collected by the author and will be released after evaluation to other investigators.

Varietal Characteristics

The following tuber characteristics distinguish varieties of *D. esculenta*: total yield, size of tuber, number of tubers borne by each plant, overall shape of tuber, tendency of tuber to branch, length of stolon, cracking pattern of the bark, presence of anthocyanin in the cortex, quantity of roots on tuber, thorniness of fibrous roots, time to maturity of the tubers, and eating quality of the tubers.

Differences among varieties with respect to foliage are not marked. With practice, the following characteristics can be distinguished: vigor of vines, pubescence of stems, presence and amount of anthocyanin in stems, size of leaf, roundness of leaf, degree of development of a tail, size of the sinus between leaf lobes, rugosity of leaf, susceptibility of foliage to leaf-spot diseases, expression of virus symptoms, tendency to flower, and sex of plant.

Among the characteristics desired in a good variety are relatively large and uniform tubers, compact tuber clusters, and few adventitious roots on the tubers. The tubers of the varieties seen in the Caribbean are usually too small for convenient handling, but are produced in suitable clusters (fig. 5). More widespread introduction and testing of newly collected varieties is desirable.

The few varietal names current in the Caribbean area and Africa have little utility because of their local nature. Varietal names in India, Indochina, Indonesia, and Papua New Guinea are seldom widespread or well known and are almost never seen in the literature.

CULTURE

Environmental Requirements

Yams are somewhat demanding in their soil requirement. The lesser yam grows very poorly in sandy soils, and the tubers are misshapen when grown in heavy clays. Tillable loams or loose clays are preferable, but good drainage is a requisite. A high level of organic material promotes yam growth.

All varieties of the lesser yam that have been grown in Puerto Rico require a particularly long rainy season. They may, in fact, not lose their green foliage during the dry season and thus may continue to grow a second season

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FIGURE 5.—A large, compact clump of tubers of the lesser yam. (One-third actual size.)

without interruption. In such a case, when vigorous new growth is resumed, the tubers gradually wither. Only when the tubers are cut free from the plant do they germinate independently and produce new plants. Thus, the tubers serve as a food reserve for the plants and are produced anew each year before the dry season.

Land Preparation

Yams are usually planted in individual hills or high ridges to provide drainage and increase aeration of the soil. In addition, yams can be harvested much

easier from ridges than from flat ground, holes, or trenches. If the soil is particularly heavy, subsoil plowing may be desirable.

Planting

The time of planting the lesser yam is somewhat more flexible than with other yams because of the capacity of the plants to grow almost year round. For practical purposes, however, time of planting is usually adjusted to conform to the beginning of the rainy season. Since the growing season is long, it is desirable to plant as soon as weather conditions are favorable. The possibility of extending the season of this yam by off-season planting needs study. Late planting has been shown in one study to reduce yields (*6*).

D. esculenta can be propagated from stem cuttings (fig. 6). Each cutting consists of a single leaf, the attached node, and a short length of each internode. Placed in mist spray, the cuttings quickly root, and small vines are formed. The technique is most useful when rapid propagation is desired from a small amount of material.

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FIGURE 6.—Single leaf stem cutting of *D. esculenta* with newly produced roots.

Normally, whole tubers are used for planting. At time of harvest there are always many tubers that are too small for convenient household use. These tubers can be used for planting the next crop. However, yields are closely related to seed-tuber size (table 1). Small seed tubers yield more per gram but less per plant than large tubers. As a practical guide, seed tubers of 50 to 75 grams are best. Larger seed tubers suitable for consumption do not yield proportionately more. At this rate and with spacing of 100 centimeters between rows and 30 centimeters between plants, the amount of planting material needed per hectare is about 2,080 kilograms.

Tubers are planted with a short hoe 8 to 12 centimeters below the surface of the ground. Atrazine, a preemergence herbicide, has been used experimentally at 3 kilograms per hectare in Trinidad

TABLE 1.—*Yield of lesser yams as related to size of seed tubers*

Seed-tuber size (grams)	Yield per plant	
	No. of tubers	Grams
15	20	400
30	26	540
45	29	590
60	31	660
75	32	680
90	34	710
105	35	735
120	36	750

after planting for weed control. Later weed control is managed by direct spraying of weeds with paraquat at 3 liters per hectare. Before atrazine and paraquat can be used commercially in the production of yams, however, they must be approved by local jurisdictions.

Fertilization

The question of mineral fertilization of yams needs further investigation. After planting, the initial growth of the yam is sustained principally by the tuber. Six or eight weeks later the principal sustenance is drawn from the soil. Thus, fertilization is most effective if given when needed. Nevertheless, application at this time is more costly and less precise. A compromise may be to bury the fertilizer under the ridge before planting, where it can be reached by the roots of the growing plant.

Generally the lesser yam responds positively to nitrogen applications, except in the latter half of its growth cycle when it is desirable to increase tuber rather than vegetative growth. On the other hand, potassium is needed especially during tuberization. Phosphorus is removed very efficiently from the soil by yams and seldom is a limiting factor in growth.

In Trinidad, the following fertilization schedule has been recommended for the lesser yam (*1*): apply either 200 kilograms ammonium sulfate per hectare 3 months after planting or 400 kilograms compound fertilizer high in potassium (11:11:13) per hectare 6 to 8 weeks after planting. However, local trials with fertilizer are always desirable.

Staking

The plants of the lesser yam climb by twining and need some kind of climbing support for maximum growth. Any stake that permits growth up to about 2 meters is probably adequate. Living plants used as supports compete excessively with the yams and reduce yields. Although some varieties of yams can produce adequate yields without staking, lesser yam tubers from unstaked plants seldom reach an adequate size. Poor yield is closely associated in this case with poor vine development.

Pests and Diseases

One advantage of the lesser yam is its relative freedom from pests and diseases. The foliage often

has virus symptoms, but virus is probably always present and is tolerated (fig. 7). Methods are needed to test for the presence of virus and to eliminate it from selected varieties. Coursey (*5*) has listed some of the common diseases of yam. Leaf spots, of such significance in the culture of *D. alata*, are seldom a problem with *D. esculenta*. Stem dieback, often seen in *D. rotundata*, does not affect *D. esculenta*.

On the other hand, nematodes can severely affect production of the lesser yam. Root-knot nematodes (*Meloidogyne*) can be particularly destructive (fig. 8). The lesions associated with this pest are large and often infected by other organisms. The best protection against nematodes is avoidance of soils that may be contaminated and selection of nematode-free tubers for replanting.

Harvesting

Studies are lacking to suggest the limits of the lesser yam harvest season. Harvesting 10 months after planting is probably realistic. Without doubt some yams can be harvested earlier, although the tubers may be immature. Since the foliage of the lesser yam often does not die back, harvest may be delayed until or even after spring growth begins.

Because of the very succulent and fragile nature of the tubers, extreme care must be taken to remove the tubers from the ground. This is normally done with hand tools, but commercial potato-digging devices can be used also. These may damage the tubers if not carefully used. Tubers must be cut from the crown and may then be washed and dried. Damaged tubers should be processed or used up as rapidly as possible.

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FIGURE 7.—Normal lesser yam leaf (*left*) and two leaves affected by mosaic virus disease.

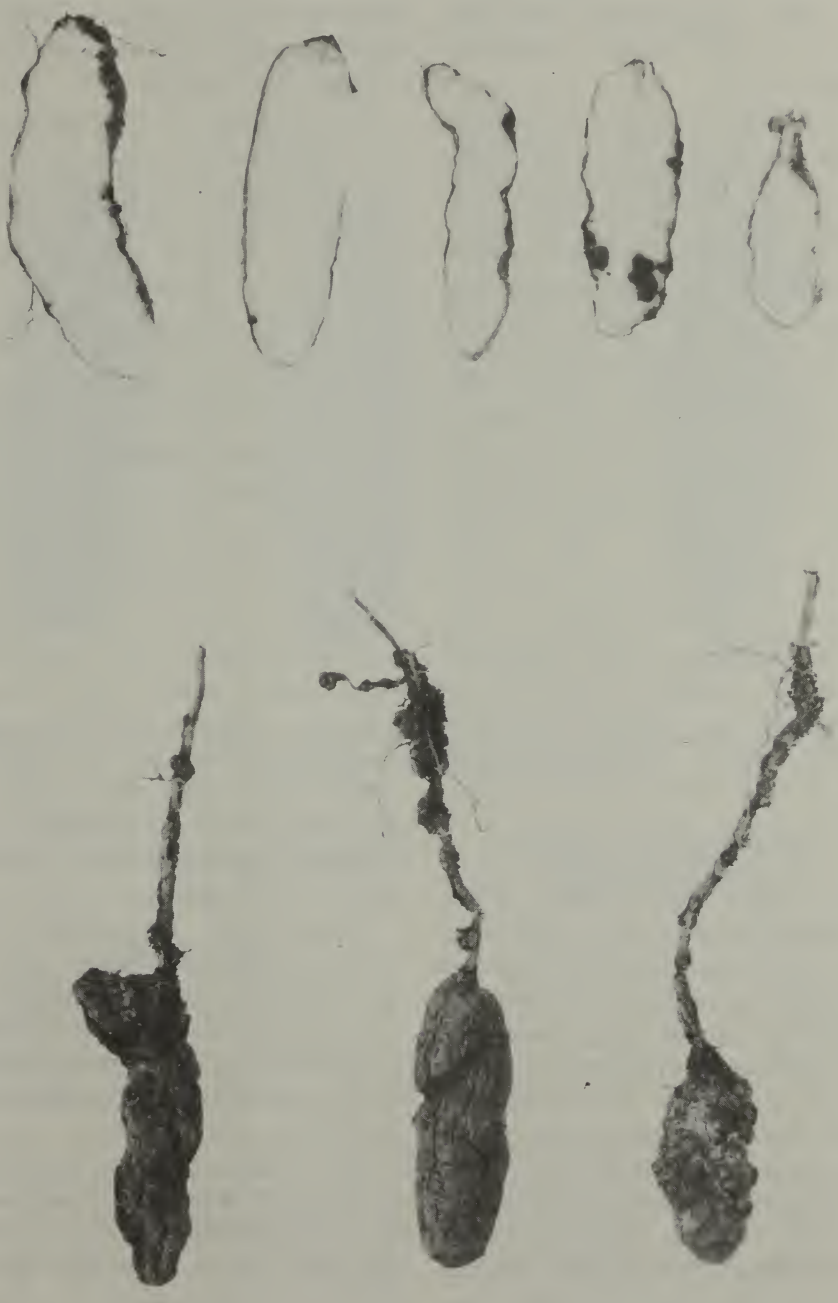

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FIGURE 8.—External and internal lesions in lesser yam tubers, associated with nematode damage.

The yams can be sorted best in the field and packed into containers that permit maximum aeration.

Individual tubers of *D. esculenta* of more than 1 kilogram have been reported. The majority of the tubers of the Caribbean varieties, however, weigh several hundred grams, somewhat less than an average potato. Yields of 25 to 45 metric tons per hectare have been reported. These yields compare favorably with those of other yam species and of any other root or tuber crop. Maximum yields at the Federal Experiment Station, Mayaguez, P.R., of 55 metric tons per hectare were obtained with seed yams of 135 grams planted in hills spaced at 60 by 60 centimeters. Some of the larger tubered varieties from New Guinea would probably outyield any of the varieties tested so far.

STORAGE AND MARKETING

Reports on storage behavior are contradictory, probably because the lesser yam is easily damaged during harvest, and once damaged, subject to rapid rotting. Under favorable, dry conditions, superficial scrapes and clean wounds can be healed, but when ventilation is poor and the tubers are kept damp, fungal growths rapidly destroy the tubers. An arrested fungal development is much more rare in this than in other species. A common practice in Puerto Rico is to treat newly harvested yams with wood ashes. This treatment probably impedes fungal growth by both chemical and physical means.

Uninjured yams may be stored for satisfactory periods. Four months is generally mentioned as the maximum storage life, but satisfactory storage of up to 8 months has been reported. In New Guinea storage life is closely related to variety and ranges from 5–6 to 12–14 months. Larger tubers store better than small tubers. During storage, respiration continues, and loss of dry matter and water occurs. Thus, the small tubers shrivel. Sugars are released, and sweetness increases. Changes in flavor, unacceptable to some persons, occur. Stored tubers usually sprout (fig. 9), especially under somewhat moist conditions. These sprouts rapidly reduce the weight and quality of the stored tuber. Tubers stored as long as 9 months have been germinated satisfactorily.

Appropriate temperatures for storage have not been investigated. Most yams are subject to injury by cool (15° C or less) temperatures. Short-term storage in the household refrigerator is practical.

The lesser yam is normally grown for home use or is marketed in small quantities or under limiting conditions. Except under limited circumstances, it cannot be considered an item of commerce. Even in New Guinea, marketing is managed chiefly on a

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FIGURE 9.—*Left*: Multiple sprouting characteristic of lesser yam tubers in storage. *Right*: Normal sprouting.

small settlement or village scale. Tubers are frequently not sold for cash, but are traded.

COOKING

Because of their small size and smooth exterior, yams of *D. esculenta* can be cooked without peeling. After boiling, the peel can be easily removed before serving. When yams are baked, the skin hardens and cannot be easily removed. Opened, baked yams are eaten with spoon or fork. The skin of the yam is too hard to eat either boiled or baked. The presence of peel affects the taste of the cooked product.

When yams are peeled with a potato peeler the amount of fresh weight lost is only 5 percent or less. The peel is easily removed because of its thinness and the smoothness of the yam. Tubers of the lesser yam can be peeled efficiently with electric potato-peeling devices.

When boiled, lesser yams erode excessively. The amount of erosion can be controlled by boiling for no more than 10 minutes. Boiled yams can be mashed. This exposes the fibers and makes it possible to sieve them out. Mashed yams often have a slightly gray color, which is not appetizing.

However, this differs with varieties. Yams have a fine texture and feel moist in the mouth.

The lesser yam is well suited for french fries and fried chips. Of common commercial fats, corn oil yields the best product. Lesser yams have rather bland flavors that are not as attractive to many as the rich, distinctive flavors of *D. alata* and *D. rotundata*. Because of their high sugar content, lesser yams are not as satisfactory for making instant flakes as are other yams.

COMPOSITION

In common with other yams, the chief nutrient of the lesser yam is starch. As previously mentioned, this makes up about 20 percent of the fresh weight of the tuber. It is a fine-grained starch with relatively low amylose content.

A second important ingredient is protein. Sufficient protein occurs in the lesser yam to be of some value in the diet. Average protein contents, for example, are four times that of cassava. The amino acid balance, however, is poor (table 2). Sulfur-bearing amino acids, methionine and cystine, are especially low and limiting. Lysine and tyrosine contents are somewhat low. Investigators have reported low tryptophan content. Thus, the protein quality is not especially good.

The protein of yams is in the form of water-dispersible gums. These exude rapidly when a yam is cut and give a slimey feel to the cut surface. The gums impede the extraction of starch. Excess amounts of water are necessary in starch preparation to disperse the gums and to let the starch precipitate. On cooking the yam, the slimey, or mucilaginous, character is lost.

The sugars present in quantities sufficient to influence taste are glucose and fructose.

POTENTIAL USES

The chief potential use of the lesser yam is as a starchy food in tropical diets, a role it already has in some areas. Because of its fine, easily digested starch and its high protein content, it should be preferred to some other starchy staples. Some varieties low in sugar might be used for fried chips. The starch may have special applications in some processed foods. Flour prepared from dried slices of tuber is sufficiently glutinous to substitute for part of the wheat flour in conventional cookery.

The characteristics of the lesser yam make it attractive for the home garden and suggest that it would be a profitable commercial crop. It yields well. Moreover, the size and shape of the tubers of some varieties would make mechanized planting and harvesting possible. Because the lesser yam is highly disease resistant, plantations need little care. The principal defect of many varieties—their susceptibility to rot and generally poor storage characteristics

TABLE 2.—*Protein and amino acids in six cultivars of* D. esculenta[1]

Cultivar	Protein	Alanine	Valine	Glycine	Isoleucine	Leucine	Proline	Threonine	Serine	Methionine
15081 de Papa	8.2	6.6	4.0	4.1	2.7	6.1	4.6	4.0	7.1	1.4
15090 de Pana	9.3	4.5	4.9	4.0	3.5	7.6	5.2	4.1	5.7	1.6
15473 Trinulenta	8.9	4.1	4.6	3.9	3.8	7.1	4.6	3.9	9.3	1.3
15215 Fasciculata	3.4	4.1	5.0	3.9	3.8	7.1	4.6	4.3	6.4	1.6
15213 Spindle	8.7	4.8	5.2	4.1	4.3	8.6	4.6	3.9	7.2	1.6
15214 Assam	7.9	5.3	5.1	4.5	4.0	8.8	4.9	4.0	6.0	1.8

	Hydroxy-proline	Phenyl-alanine	Aspartic acid	Glutamic acid	Tyrosine	Lysine	Histidine	Arginine	Cystine
15081 de Papa	0.18	4.1	9.4	12.1	2.6	3.8	3.3	23.4	0.17
15090 de Pana	.13	5.0	11.1	12.6	3.2	3.9	2.8	20.0	.16
15473 Trinulenta	.20	4.6	9.6	11.6	2.8	3.9	3.2	21.1	.12
15215 Fasciculata	.08	5.4	12.2	12.2	3.3	3.6	2.4	18.1	.18
15213 Spindle	.12	5.9	12.5	13.2	3.0	4.0	2.8	13.7	.22
15214 Assam	....	6.0	13.6	13.8	2.7	3.8	2.7	13.0	.12

[1] Values of amino acids are miligrams per 100 grams of yam, dry weight. Protein content is given in percent.

—might be overcome by selection of varieties.

Before the potential of the lesser yam can be fully evaluated, the available germ plasm will have to be more thoroughly studied. Many new varieties, believed to represent a cross section of the existing variation, have been collected. Some appear to combine the best features for which this species is noted and seem to be free of the serious defects of the small-tubered cultivars. These better cultivars indicate that the lesser yam has been underrated and that it may yet play an important role in a hungry world.

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